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GROUND LIGHTING EQUIPMENT

M. Gouet

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16. Abstract

Discussion of the ever-increasing importance of visual aids in the equipment of airports. For minimums in Categories I and II, visual aids can serve to guide aircraft, although for Category II it is too late to make major corrections when the lights come into view. The first consequence of the lowering of visual minimums is the absolute necessity of standardization of beacons to make it possible for the pilots to decide immediately whether or not to complete the landing. Light distribution depends on three main factors: (1) the degree of the aircraft's deviation from the ideal flight path, (2) the minimum optical range of the lights necessary for each phase of the approach, and (3) the field of vision downward from the aircraft. Lighting equipment used in France is briefly described.

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M. Gouet

I. ROLE OF VISUAL AIDS IN DIFFERENT OPERATING CATEGORIES

The lowering of operational minimums, far from minimizing the usefulness of visual aids upon landing, confers even greater importance upon them and hence involves stricter requirements for both lighting devices and the materials used. /1*

We will first recall the minimums adopted for various operating categories:

- Category I operation: operation up to a decision altitude of 60 meters and a runway visual range of 800 m.
- Category II operation: operation up to a decision altitude of 30 m and a runway visual range on the order of 300 m.
- Category III operation:
  - III A - operation up to runway visual range of 200 m.
  - III B - operation up to the runway visual range on the order of 50 m, sufficient for visual movement on the ground.
  - III C - operation without visual observation of landmarks.

We can now pass to the role of visual aids in the above-listed categories.

Categories I and II. Visual aids must serve for aircraft guidance. In the case of category II operation, when the pilot changes over to visual navigation, it is too late to make major course corrections: the pilots will immediately go into a failure approach if they judge that they are wrongly aligned when entering visual navigation. Otherwise the device must aid in completing the landing.

Category III A. Non-visual aids must ensure effective guidance /2

*Numbers in the margin indicate pagination of the foreign text.

up to touchdown. However, the pilots will be able to rely on visual aids during the final level-off and landing phase which will enable them to decide whether to land or to go-around.

Category III B. Category III B operation requires much greater reliance on non-visual aids for the complete landing phase and visual observation ensuring the necessary guidance for travel on the ground. It is probable that visual aids will serve the pilot to steer immediately after round-out: in fact tests have shown that pilots can steer a high-speed aircraft to the ground with a very short segment.

Category III C. Visual navigation is no longer required since all landing and ground travel operation are performed electronically.

II. EFFECTS ON LIGHT BEACONING DEVICES

A. The first effect of the lowering of minimums is an absolutely essential standardization of light beacons starting from category II operation. At the time of transition to visual navigation, and as soon as the beacon is visible, the pilots must have immediate confirmation as to whether they should continue to land or not.

If we consider the operational conditions of Category II for a cockpit angle of 15° the only section of the beaconing system that the pilots can perceive is the last 300 meters of the approach line. This being the case, the visual guidance segment covers a section of between 90 and 120 meters, and the maximum time available to the pilot to determine his position will be about 7 seconds before passage to the threshold. Evidence shows that the amount of information the pilot can absorb under these conditions is strictly limited, and is only useful if these 300 meters of the approach line are absolutely standardized.

Two approach line devices are ICAO-approved at this time. /3
However, the organization has been able to agree upon a

standardization of the last 300 meters, a very exact description of which appears in Appendix XIV. This is presently in the form of a recommendation but will probably become mandatory before long.

B. The effects of transfering to category III operation.

1) Transfer to category III A will entail a concentration of lights in the landing zone. This is not scheduled after the first experiments on change of configuration with respect to category II operation: only the spaces between lights could be altered, as could the required intensities. Current research is testing threshold lights, round-out area lights, and runway center line lights.

2) Transfer to category III B will involve a reinforcement of the beacons used by the pilot during travel on the ground: runway center line, runway exits, and taxiways. This beaconing will be a complex problem due to the length of the taxiways to be lighted and the chances of crossing on the ground.

III. PRESENT-DAY SYSTEM

It would take too long to give a complete description here of the devices chosen by the ICAO and appearing in Appendix XIV. A photograph will be sufficient to give an idea of this system.

It will probably be of more interest to dwell on the characteristics of the lights in the system. In its fourth meeting in 1966, the ICAO visual aids group reached agreement on a text establishing the theoretical distribution of intensity to be obtained from beacon lights:

a) Degree of the aircraft's deviation from the ideal flight paths. /4

b) Minimum optical range of lights necessary for each approach phase, allowing for the range of visibility conditions under which these lights must provide guidance.

c) Field of view downward from the cockpit.

Transfer to categories I and II demands a higher light intensity. At the same time the size of the deviations becomes smaller. We thus have the opportunity of decreasing the beam apertures while increasing their intensity. Unhappily the lights used in categories II and III will also be used, in the same airports, by aircraft operating in category I. Hence, for category III, we are led to increasing the intensity of the lights while retaining their present aperture.

Another difficulty arises from the use of colors in the approach system. In order to give the system a desirable appearance, it has been deemed appropriate that the intensity of the lights employed in adjacent sections of the lighting system should not differ too greatly. The minimum average intensities so defined and recommended are as follows:

- approach axial light (white)	20,000 cd
- side strip light (red)	5,000 cd
- runway edge light (white)	10,000 cd
- runway center-line light (white)	2,500 cd (for 7.5 m spacing)
	5,000 cd (for 30 m spacing)
- round-out area light (white)	5,000 cd
- threshold light	10,000 cd

The beam aperture was defined with regard to the fact that there could be confusion in the appearance of the system if the lights had wide variations in intensity according to the angles of view at which they could be seen during approach. At no point of the beams so defined must the intensity be less than half the average intensity of the beam.

Obviously the apertures vary widely from one type of light to /5 another. As an example, for green threshold lights, the beam aperture in which the average intensity must be 10,000 cd is 11°

laterally ($\pm 5°$) and 5-1/2° vertically. This makes it one of the most difficult lights to design.

IV. EQUIPMENT USED IN FRANCE

A. ABOVE-GROUND EQUIPMENT

The classic projectors easily give the intensity and beam aperture recommended by ICAO. The wattage used is as follows:

500 W or 250 W for approach lights, 200 W for runway edge lights, and 500 W for threshold and red side strip lights.

The peak intensity obtained with a 500 W lamp is on the order of 60,000 cd with white light.

B. BUILT-IN EQUIPMENT

On the other hand, to meet ICAO specifications, it was necessary to investigate new materials destined to be built into the runway or its extension. Because of the present tendency to lengthen all runways, most airports presently have a displaced threshold, due to surrounding obstacles.

As a result, not only the equipment intended for equipping the runway but also that destined for equipping part of the approach line, in particular its last 300 meters, must be built-in.

These built-in lights, due to their position, must allow the aircraft to travel over them without hindrance. The maximum jut-outs deemed appropriate are as follows:

threshold lights:	40 mm
approach lights:	20 mm (planes taking off only)
narrow way lights:	15 mm
runway center-line lights:	6 mm

To obtain light intensities meeting ICAO specifications with such small visible optical surface, it has been necessary to resort /6 to iodine-vapor incandescent lamps. Due also to the very short focal lengths of the lights, it was necessary for the required accuracy to make lamps with a pre-focused tube base, namely the position of the filament with respect to the light's optical focus is guaranteed. The focussing accuracy obtained is ± 0.1 mm.

The equipment used in manufacturing built-in lights is as follows:

1. the base is made of aluminum alloy permitting precise molding;
2. the cover is either in malleable cast iron or in aluminum alloy, so that both have the desired mechanical strength.

The various types of lights are as follows (a photograph of each light will illustrate the text below):

1. Runway center-line lights:

diameter:	200 mm
depth:	40 mm
jut-out:	6 mm

The intensity obtained in the center-line is about 1500 candle-power. The lamps are powered in series per group of five lights, and each lamp is shunted by an electromagnetic relay whose purpose is to short-circuit the lamp if the filament breaks such that only the defective light goes out.

2. Round-out area light: 100 W

diameter:	200 mm
depth:	60 mm
jut-out:	15 mm

The intensity obtained in the center-line is more than 15,000 candlepower. These lights are installed in groups of three on each side of the runway, leaving a gap of 22.5 meters on the first 900 meters of the runway. They are powered in series per group of three lights, and the lamps are shunted as above.

3. Approach and threshold lights: 750 W.

These lights are to equip that part of the approach lines situated in a zone that can be traveled. The dimensions are as follows:

width:	400 mm
length:	800 mm
depth:	400 mm
weight:	over 100 kg

These are large pieces of equipment, and a great deal of earthwork must be done in the runway. The light is fixed on a cast iron frame, itself sealed absolutely horizontal to the runway.

The optics of the light are formed of three identical components comprising:

One iodine lamp: 250 W
One eliptical mirror
One total reflection prism

The light can be built in two different ways: either jutting out 40 mm (for thresholds and side strips) or 20 mm (for the axial approach line). The maximum intensity obtained is 60,000 and 30,000 candlepower respectively.

Installation of these lights involves a number of problems in both construction and maintenance: lifting vehicles have been designed for 750 W lights weighing over 100 kg.

But the main problem remains the attachment of the lights to the runway. At first their seating involved the following operations:

1) Cutting out a cavity with a diamond crown.
2) Smoothing the cavity with the aid of a pneumatic chisel. The surface of the base of the cavity must be perfectly regular.
3) Making the cable runs with a concrete saw fitted with carbide blades.

Next the lights must be set in place--by experts in view of the necessary accuracy. This includes:

1) Preparation of the light's cavity, which involves compressed air sand blasting, cleaning the cavity, drying with a propane torch, and heating the concrete such that, 10 minutes later, the temperature is between 20 and 30°.
2) Preparation of light, involving the same operations.
3) Preparation of glues. /8

Special glues have been investigated. The criteria of a good glue are that it should:

- adhere firmly to the metal and the concrete;
- have good strength with fluctuating temperatures: the temperature of the lights when switched on rises sharply, up to 60 or 65 degrees according to type;
- have good water resistance;
- preserve mechanical properties over time;
- modulus of elasticity must not be too high.

The glues must be very accurately weighed for each light (2 kg $\pm$ 1 g glue for a 45 W light).

4) Installing lights. When the glue has been placed at the bottom of the hole, the light is sunk in gradually by vibration. Adjustment is done with a sight glass. The accuracy obtained is 1 minute.

Experience from the first runway center lines installed has shown that the lights had very good impact strength when aircraft passed over them, and the adjustment remained correct.

V. WORK IN PROGRESS: CONCLUSION

1. As has been seen above, the investigations on transfer to category III A operation are at present chiefly directed to the lights used in the landing phase, during takeoff, or during taxiing. Work coordinated by the ICAO secretariat is presently

underway in different countries on threshhold, center-line, round-out
area, and taxiway lights. It seems at present that it will be use-
ful to color-code the runway center line, and various coding
devices are now being tested.

2. We have deliberately confined this report to light beacon-
ing, but we must not fail to mention the usefulness of marks
painted on runways, particularly in the daytime with poor visibility.
Unfortunately they wear off very quickly in busy airports, especial- /9
ly near the center line where the aircrafts quickly deposit a layer
of rubber.

3. This report was necessarily very brief. Our wish was to
give some insight into the increasing importance of visual aids
in airport equipment. For example, a 3000 m runway with a thresh-
hold displaced by 300 meters, if equipped for category II operation
according to ICAO standards, would have more than 200 above-ground
projectors and nearly 700 built-in lights of which about one
hundred would be 750 watts.